Parasitization of the BEET LEAFHOPPER in Relation to Its Dissemination in Southern Idaho

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THE BEET LEAFHOPPER is a serious menace to sugar beet, tomato, and other crops in the West because it is the only known carrier of curly top disease, which it transmits to these and many other plants. Since 1950 there has been renewed interest in the possibility of utilizing natural enemies for the control of this insect, as a result of the recent general acceptance of the idea that it is not native to North America.

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Parasitization of the BEET LEAFHOPPER in Relation to Its Dissemination in Southern Idaho[1]

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In Cooperation With the Idaho Agricultural Experiment Station

The beet leafhopper (*Circulifer tenellus* (Baker)) travels long distances between its overwintering breeding areas and cultivated districts or summer breeding areas. In California flights of 200 to 300 miles were noted by Annand (*1*).[3] During the spring of 1931 leafhoppers traveled 250 to 300 miles into sugar beet areas of central Utah (Annand and Davis *3*). A movement of 150 miles from the spring breeding areas in the foothills of California to the Sacramento Valley was indicated by Severin (*13*). In spring flights in New Mexico the insects traveled 250 miles, and by early summer there was a gradual influx of leafhoppers from the spring breeding areas of New Mexico into southeastern Colorado, 430 miles away (Romney *12*).

Studies were made in southern Idaho from 1930 to 1937 to determine the effect of parasitization on the ability of the beet leafhopper to move long distances, and the effect of leafhopper movements on the dissemination and distribution of its parasites.

Seasonal Movements

In southern Idaho large numbers of beet leafhoppers develop during the summer on Russian-thistle (*Salsola kali* var. *tenuifolia* Tausch), which grows principally on abandoned land within and adjoining the cultivated districts (Haegele *9*, Carter *4*, and Annand *et al.* *2*). The environment has changed in recent years so that today most of the Russian-thistle is growing on overgrazed rangeland. In the fall when the thistle becomes dry the leafhoppers move to other areas to find suitable food.

The possibility that contiguous sagebrush areas were favorable overwintering habitats for beet leafhoppers moving from the Russian-thistle summer breeding areas was first suggested by Carter (*4*). Piemeisel and Chamberlin (*11*) and Fox (*5*) later concluded that sagebrush (*Artemisia tridentata* Nutt.) interspersed with fall germinating annuals provides the most abundant supply of green plants for leafhoppers to feed upon in the fall.

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[2] The writer is indebted to D. E. Hardy, formerly of the University of Kansas, for identifying the Dorilaidae collected during these studies and to the following persons of the former Bureau of Entomology and Plant Quarantine: J. R. Douglass, F. H. Harries, D. E. Fox, and W. E. Peay for their valuable assistance; and P. W. Oman for identifying the leafhoppers.

[3] Italic numbers in parentheses refer to Literature Cited, p. 16.

The spring generation of the beet leafhopper in these sagebrush areas develops on annual plants such as mustards (Haegele *9*, Carter *4*, and Annand *et al. 2*). Piemeisel and Chamberlin (*11*) and Fox (*5*) indicated the distribution and importance of green tansymustard (*Descurainia pinnata* var. *filipes* (A. Gray) Peck) as a spring breeding plant in the sagebrush areas of southern Idaho. The annual mustards disappear early in the season, and the leafhoppers disseminate to the cultivated fields and to adjacent or distant areas where Russian-thistle occurs.

The flights of the beet leafhopper between the summer and the overwintering and spring breeding areas cover many miles and have an important effect on the parasitization of this insect.

Effect of Parasitization on Movements

Many of the leafhoppers moving between the summer and winter breeding areas contain larvae of various parasites. The presence of these larvae undoubtedly affects the ability of the leafhoppers to reach the upper air currents, where they can be transported for long distances. Parasitized insects are usually sluggish and tend to hop along the ground rather than fly into the air, where they might be carried by the wind. Furthermore, parasitization makes sustained flight more difficult, as the leafhoppers expend considerable energy in flight, as indicated by Fulton and Romney (*7*), even though they are carried largely by air movement.

Severin (*13*) stated that in California leafhoppers of the fall generation that were parasitized by large larvae remained in the cultivated or summer breeding areas, whereas those containing tiny larvae flew to the winter breeding grounds in the foothills. He concluded that parasitization was lowest on the uncultivated plains and in the foothills.

It appears that parasitization within a secondary breeding area depends upon the degree of parasitization in the primary breeding area, the size of the parasite larvae at the time of flight, and the distance between the two areas. The size of the parasites varies with the time of year. During the fall movements of 1934–37 the parasite larvae dissected from female beet leafhoppers were small, averaging 0.86 mm. in length, whereas those from leafhoppers entering the beetfields in the spring of 1937 were approximately half-grown, averaging 1.42 mm. in length. Therefore, parasitized leafhoppers probably travel farther in the fall than in the spring in southern Idaho.

Methods of Parasite Dissemination

It is possible that adult parasites may be transported in the upper air currents in the same manner as the host. Glick (*8*) collected large numbers of parasitic Hymenoptera and Diptera in the upper air over Louisiana and Mexico. Included were specimens of the family Dorilaidae (=Pipunculidae), members of which are parasitic on leafhoppers. However, this is not believed to be an important method of disseminating beet leafhopper parasites.

From 1930 through 1934 many air-maze traps (Fulton and Chamberlin *6*) were maintained in southern Idaho for studies of the flight

associations of various insects common to the area. All trapped specimens were identified, and although 2,813 beet leafhoppers were collected during the 5-year period, only 7 adult leafhopper parasites were taken and all were Dorilaidae. It is evident that no large-scale dissemination of adult leafhopper parasites had occurred.

The most important method of dissemination of beet leafhopper parasites from one breeding area to another is undoubtedly through the movement of the host. In southern Idaho this insect is parasitized by species of Dryinidae (Hymenoptera), Stylopidae (Coleoptera),[4] and Dorilaidae (Diptera). The probable means of parasite dissemination in each of these families are discussed below.

Dryinidae

The Dryinidae females that attack beet leafhoppers in southern Idaho are wingless, and therefore cannot fly from one area to another. The males are delicate-winged creatures, and some are undoubtedly carried by air currents, although it is evident that the dissemination of males alone is of no practical importance. Dispersal by the wind is apparently of little consequence in this family, since no specimens were observed in the trap collections during 1930–34. Even though a few adult females might be transported in the upper air currents, the chances of their reaching a favorable habitat and finding suitable hosts in which to oviposit are rather slight. The most effective method of dissemination for the Dryinidae, therefore, is through the movement of leafhoppers containing the larvae, particularly the early instars. When transported as larvae within the hosts the parasites obviously would reach the same general environment, and should therefore have less difficulty in finding suitable hosts than if they were carried as adults by the wind.

Stylopidae

Female stylopids spend their entire life cycle within the body of the leafhopper, except for the brief period that they are first-instar larvae, or triungulinids. Thus they are dependent for dissemination almost entirely upon the movement of the host. Since immature stages of various insects are carried by air currents, the tiny triungulinids may occasionally be distributed in this manner. However, their chances of attaching themselves to a favorable host after this type of dissemination are very slight. When the parasite eggs hatch, the triungulinids leave the body cavity of the female through an opening in the cephalothorax to seek another host (fig. 1). For this short interval the parasite might be picked up and transported by air currents.

Male stylopids are free moving at this stage and again when they become adults. The male pupates within a sac consisting of the last larval exuvia, its cephalothorax protruding from the host's abdomen. Upon maturing the male emerges as a winged adult. This stage is exceedingly short lived. Indications are that few males are transported by the wind, since none were found in the air-maze traps from 1930 to 1934.

[4] Given ordinal rank by some authors as Strepsiptera.

FIGURE 1.—Cephalothorax of an adult female *Agalliaphagus americanus* (Perkins) protruding between the fourth and fifth abdominal segments of an overwintering female beet leafhopper.

Dorilaidae

In contrast to the Dryinidae and Stylopidae, both males and females of the Dorilaidae are strong fliers, and the hovering habit, especially of the females while in search of leafhoppers in which to oviposit, makes them particularly susceptible to air currents. Many adults of these parasites are carried into the breeding areas by the wind, although trap collections indicate that this method of dissemination is much less important than the transportation of larvae within the dispersing hosts.

Sweep-net collections taken above plants in heavily infested patches of Russian-thistle indicated that few leafhoppers containing fully grown dorilaid larvae reached sufficient altitudes to be carried away by air currents. The abdomens of leafhoppers parasitized with large larvae are greatly swollen and the conjunctivae are distended (fig. 2).

FIGURE 2.—Overwintering female beet leafhoppers: *A*, Parasitized leafhopper with swollen abdomen and distended conjunctivae; *B*, unparasitized leafhopper.

When disturbed these insects hop sluggishly, in contrast to the normal flight of unparasitized insects.

Fall Movement to Overwintering Areas

To determine whether leafhoppers move into the Sailor Creek sagebrush area for overwintering and, if so, to establish the approximate time of such movement, collections were made on a transect from Bliss to Balanced Rock at intervals in the early fall of each year from 1934 to 1937 (fig. 3). This transect was along the eastern border of

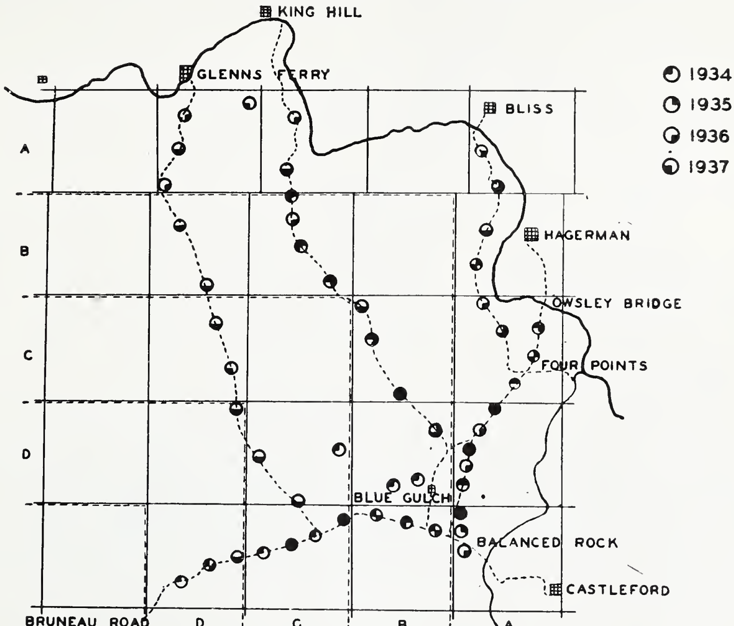

FIGURE 3.—Transect routes and approximate collection points of leafhoppers in the Sailor Creek sagebrush area, 1934–37. The strips *A*, *B*, *C*, and *D* represent 6-mile intervals from the northern and eastern borders of the area.

the Sailor Creek area, where the insects would arrive first in their flight from the drying Russian-thistle.

During 1935 practically no beet leafhoppers were in this area until September. By September 18 a slight influx occurred, averaging 0.2 male and 0.1 female per square foot of sagebrush and by October 1 0.6 male and 0.6 female.

After moving to the overwintering areas, the leafhoppers remain on the sagebrush foliage until low temperatures prevail. Then they drop to the ground and are found thereafter beneath the sagebrush plants, especially where plant debris is present for protection. Normally winter annuals, such as green tansymustard, have not germinated at the time of the fall movement; so the leafhoppers remain for some time on the sagebrush.

Parasitization in Summer Breeding Areas at Time of Fall Movement

In 1935, 1936, and 1937 more than 26,000 female beet leafhoppers collected in the summer breeding areas between September 11 and October 17 were examined for parasitization. Since the fall movement was in progress, these leafhoppers were representative of those entering this movement. As shown in table 1, Dorilaidae comprised practically 98 percent of the total parasitization.

TABLE 1.—*Parasitization of female beet leafhoppers collected in Russian-thistle areas at the time of the fall movements, 1935–37*

Collection period	Collection points	Females taken	Parasitization by—			
			Dorilaidae	Dryinidae	Stylopidae	Unidentified
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Sept. 11–Oct. 17, 1935	45	8, 460	17. 9	0. 13	0. 22	0. 08
Sept. 11–Oct. 1, 1936	35	10, 900	28. 0	. 14	. 24	. 06
Sept. 14–28, 1937	47	7, 126	22. 8	. 19	. 36	. 06
Total or average	42	26, 486	22. 9	. 15	. 27	. 07
Percentage of total parasitization			97. 9	. 6	1. 2	. 3

Most of the Dryinidae were full-grown larvae, and a large percentage would probably have left the host leafhoppers prior to dissemination. Dryinidae normally enter the soil for pupation some time before the fall movement takes place. Furthermore, it is doubtful that leafhoppers parasitized with large Dryinidae could move any great distance.

The Stylopidae spend the winter within the abdominal cavity of the host insects, and most of those found were small larvae that would not greatly handicap the movement of the host. This method of dispersal is of little practical importance, however, as the numbers of these parasites are exceedingly low at this season of the year.

To determine the species of Dorilaidae, adults were collected in various areas with an insect net, and others were reared from leafhoppers collected in this manner. Of 1,024 parasites obtained from 1934 to 1937, 99.6 percent were *Tömösváryella vagabunda* (Knab) and the remainder *Dorilas subopacus industrius* (Knab), except for one specimen of *Tömösváryella subvirescens* (Loew) collected in 1936. *T. vagabunda* was also the predominant species found within leafhoppers collected in beetfields soon after the spring flight.

Parasitization of Leafhoppers Associated With the Beet Leafhopper in Summer Breeding Areas

From 1931 to 1937 large numbers of leafhoppers associated with the beet leafhopper in the summer breeding areas were dissected for determination of parasitization. The only ones of any importance occur-

ring on Russian-thistle were species of *Aceratagallia*—*fuscoscripta* Oman, *arida* Oman, *cinerea* (Osborn and Ball), and *uhleri* (Van Duzee). All specimens of these insects collected with the beet leafhopper were preserved in chloral hydrate solution and later dissected. The results are shown in table 2.

TABLE 2.—*Parasitization by Dorilaidae of the beet leafhopper and associated leafhoppers* (Aceratagallia *spp.*) *collected on Russian-thistle in the summer breeding areas, 1931–34 and 1937*

Year	Beet leafhopper		*Aceratagallia* spp.	
	Dissected	Parasitized	Dissected	Parasitized
	Number	*Percent*	*Number*	*Percent*
1931	12, 986	13. 1	1, 074	0. 09
1932	8, 815	3. 1	2, 386	0
1933	2, 897	1. 4	1, 325	0
1934	4, 456	6. 4	0	0
1937	14, 040	18. 1	2, 845	. 04
Total or average	43, 194	11. 2	7, 630	. 03

Parasitization of *Aceratagallia* by Dorilaidae was apparently of minor importance. From 7,630 adults dissected only 2 dorilaid larvae were taken. They were very small, and it is not known whether they could have completed their development in this host, or even whether the same species were parasitic on the beet leafhopper. No dorilaid adults were reared from *Aceratagallia*. It is evident that leafhoppers of this group were unfavorable hosts of the dorilaid species attacking the beet leafhopper in southern Idaho. As they were the only leafhoppers associated with the beet leafhopper, it is also apparent that the dorilaid parasites had no important alternate hosts in the summer breeding areas.

Absence of Beet Leafhopper Parasites in Sagebrush Areas During the Summer

Practically no beet leafhoppers remain within the sagebrush areas after the winter annuals become dry. This usually happens by early summer in those areas where only green tansymustard and other early-maturing plants are found, and by midsummer where late-maturing species of *Chenopodium* and *Gilia* occur. Consequently, there is a period of several months when the Dorilaidae have few host insects in which to oviposit, unless other leafhoppers serve as alternate hosts at this time. According to Fox (*5*), the sage leafhopper (*Empoasca aspersa* G. and B.) is by far the most abundant species on sagebrush either adjacent to, or some distance from, abandoned land, but other species are also usually present.

To determine whether various species of leafhoppers in the sagebrush areas serve as alternate hosts of Dorilaidae, sweep-net collections

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of these insects were taken in the Sailor Creek sagebrush area in August 1941. The results are shown in table 3.

TABLE 3.—*Parasitization of several species of leafhoppers by Dorilaidae in the Sailor Creek sagebrush area, August 1941*

Species	Unparasitized	Parasitized
	Number	*Number*
Empoasca aspersa	1,522	21
Aceratagallia spp	145	0
Phlepsius sp	57	2
Acinopterus sp	51	0
Circulifer tenellus	12	2
Xerophloea viridis (F.)	2	0
Total	1,789	25

Dorilaidae were responsible for the parasitization of only about 1 percent of *Empoasca aspersa* as compared with 14 percent of *Circulifer tenellus*. Also, the parasite larvae dissected from *aspersa* were quite different from the larvae of *Tömösváryella vagabunda* and *subvirescens* and *Dorilas subopacus industrius*, particularly with regard to the size and sclerotization of the mouth parts. The second most important leafhoppers in this area, the *Aceratagallia*, were not parasitized by dorilaid larvae. Furthermore, the aceratagallian leafhoppers associated with the beet leafhopper in the Russian-thistle summer breeding areas were practically immune from attack by members of this family. The other species of leafhoppers in the sagebrush area were rather scarce and so widely scattered that they would not have constituted an important alternate host for the Dorilaidae attacking the beet leafhopper.

From these data it appears that, unless sufficient numbers of parasites accompany the beet leafhopper to its overwintering areas, parasitization of the spring generation developing on annuals in these areas would be very low.

Parasitization of Beet Leafhoppers Moving Into Overwintering Areas

The fall movement of beet leafhoppers into the Sailor Creek sagebrush area probably was from two general sources—(1) the summer breeding areas to the east and southeast, which contained Russian-thistle and some sugar beet plantings; and (2) the Russian-thistle areas toward the north in the vicinity of King Hill and Glenns Ferry (fig. 4). Leafhoppers were taken with a Hills (*10*) sampling cage in these areas during 1934–37 before the movement into the Sailor Creek sagebrush area had begun. Similar collections were made on stands of short sagebrush in the Sailor Creek area soon after the movement had occurred each year, 50 or more females being taken at approximately 3-mile intervals on predetermined transect routes (fig. 3). The results are shown in table 4.

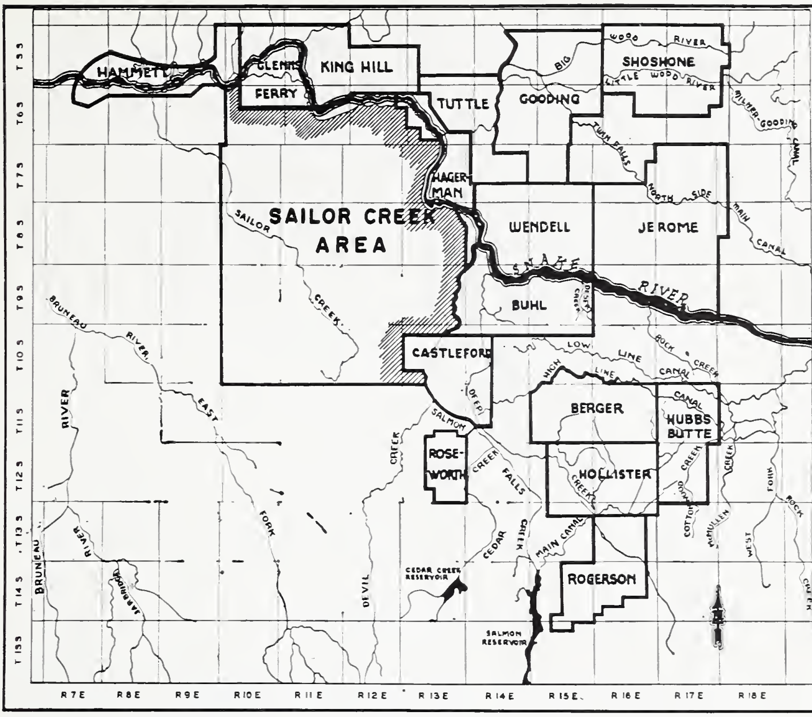

FIGURE 4.—Location of the summer breeding areas (names in heavy type within rectangles or polyhedrons) of the beet leafhopper in relation to the Sailor Creek sagebrush overwintering area.

TABLE 4.—*Parasitization of the beet leafhopper in the Russian-thistle areas and the Sailor Creek sagebrush area in the fall, 1934–37*

Year	Russian-thistle areas		Sagebrush area	
	Areas sampled	Beet leafhoppers parasitized	Transects sampled	Beet leafhoppers parasitized
	Number	*Percent*	*Number*	*Percent*
1934	15	25. 1	5	13. 3
1935	12	20. 5	4	15. 8
1936	15	34. 3	5	22. 9
1937	14	34. 4	5	22. 2
Total or average	56	28. 6	19	18. 6

It is evident that large numbers of dorilaid larvae were transported into the overwintering areas within the dispersing leafhoppers during the 4-year period, although the percentage of parasitization was significantly higher in the adjacent Russian-thistle breeding areas.

Effect of Parasitization on Fall Movement

The effect of parasitization on the distance beet leafhoppers travel during the fall movement was studied in 1934–37. As the Russian-thistle and cultivated areas already contained parasitized leafhoppers, such determinations could not be made until they reached the Sailor Creek sagebrush area, where practically no parasitized leafhoppers were present prior to the fall movement. During October and November of each year beet leafhoppers were collected at various points in this area and examined for parasites. The percentage of parasitization at each point was then plotted against the distance from the northern or eastern border, whichever was closer, and the regression coefficient calculated. Negative coefficients were obtained for all 4 years, although three of them were not significant and the fourth was barely significant. These results indicate a slight tendency toward decreased parasitization as the distance into the sagebrush area increased. However, differences in parasitization at the source of the movement might be reflected in the collections within the sagebrush area.

All the parasites within the leafhoppers reaching the sagebrush area were small, probably because the leafhoppers bearing the larger larvae had dropped out.

Spring Movement to Summer Breeding Areas

To establish the time of movement of beet leafhoppers from the overwintering and spring breeding areas to the beetfields and summer breeding areas, leafhoppers were collected in 6 beetfields at the western edge of the Sailor Creek sagebrush area from May 28 to June 20, 1937. All leafhoppers from 100 beet plants taken at random were collected with a Hills sampling cage and held in a 5-percent aqueous solution of chloral hydrate for dissection.

A few male beet leafhoppers were found in several fields on June 1. Since males do not overwinter in southern Idaho, their presence in the spring indicates the appearance of the spring generation. No parasites were found within the female leafhoppers taken before June 1. On that date 1.2 females per 100 plants contained dorilaid larvae from 1.1 to 1.7 mm. long. These leafhoppers were known to be of the spring generation, since they were lighter in color than the overwintering forms. By June 3 the influx of leafhoppers was well under way, and 8.2 parasitized spring-generation females were found per 100 plants.

The adult leafhoppers found in the beetfields bordering the sagebrush areas during the first 4 days of the movement contained parasite larvae averaging 1.3 to 1.5 mm. in length. No first- or third-stage larvae were found within these leafhoppers. It is evident that leafhoppers bearing fairly large parasites moved this short distance into the cultivated area.

To compare the degree of parasitization before and during the spring movement, samples of leafhoppers were taken at the same time on green tansymustard growing beneath the sagebrush plants in the Sailor Creek area. Table 5 shows that parasitization was much higher in the Sailor Creek area than in the nearby beetfields. Since

the exact source of the incoming leafhoppers was not known, it was impossible to determine how much of this reduction was due to the decreased ability of the parasitized insects to fly.

TABLE 5.—*Parasitization of female beet leafhoppers in the Sailor Creek sagebrush area and in 6 adjoining beetfields, 1937*

Sampling period	Sailor Creek area	Beetfields
	Percent	*Percent*
May 28–June 1	5. 0	4. 7
June 3–4	25. 8	9. 1
June 9–11	51. 2	9. 4
June 16–20	41. 6	9. 4
Average	30. 9	8. 2

To determine the relationship between the distance traveled within the cultivated area and the reduction in parasitization, 27 beetfields were similarly sampled between June 11 and 13, 1937.

Leafhopper counts indicated that most of the movement had been from the northwest. As shown in figure 5, the average number of adult females gradually decreased from 7.9 per plant in the northwestern corner of the cultivated district to 0.6 in the southeastern corner.

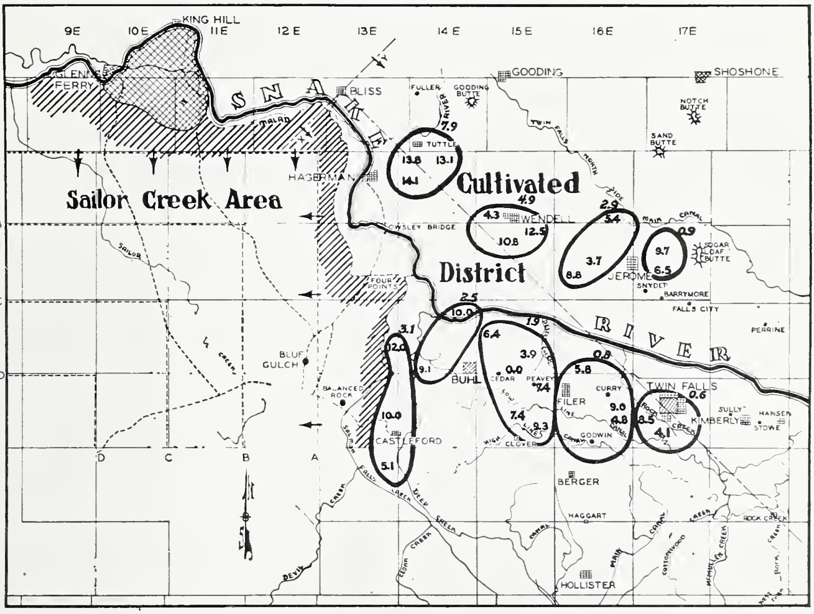

FIGURE 5.—Parasitization of beet leafhoppers in the Sailor Creek sagebrush area and the adjoining cultivated district, 1937. Numbers within the areas enclosed by heavy lines represent the percentage of parasitization in the various beetfields and numbers just above the enclosed areas the average number of female beet leafhoppers per plant. The crosshatched section south of King Hill is a large Russian-thistle area.

The percentage of parasitization in the various fields was correlated with the distances traveled, as shown in figure 6. The regression coefficient was significant and negative, indicating decreased para-

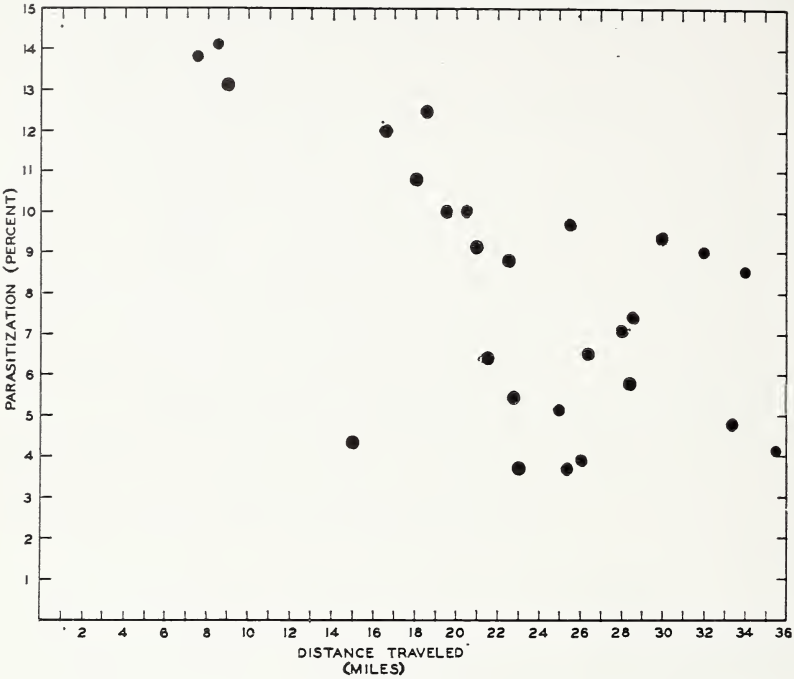

FIGURE 6.—Percentage of parasitized female beet leafhoppers after various distances of flight within the cultivated area during the 1937 spring movement into the beetfields.

sitization as the distance of travel increased. This finding would be expected because of the large size of the parasites at this season of the year. As with the fall dispersal, the distances toward the end of the flight were used in these calculations, and it is probable that the reduction in parasitization was most rapid at short distances from the source.

The results of these reductions in parasitization could be of great importance where long-distance movements occur. If rates of decrease over long distances are comparable with those over relatively short distances, few parasites within spring-generation leafhoppers would reach an area 150 miles or more from the source. Movements of this distance or greater, as previously shown, are not uncommon for the beet leafhopper.

Internal parasites of insects that move long distances are always at a disadvantage in reducing host populations. Before the parasites have time to reduce their numbers greatly, the leafhoppers move with a consequent decrease in parasites.

Fall Parasitization as an Indication of Parasite Overwintering Areas

In the falls of 1934–37 the percentages of beet leafhoppers parasitized by Dorilaidae just prior to overwintering were determined in a large number of Russian-thistle areas in southern Idaho from Mountain Home on the west to Rexburg on the east. Similar studies were made in the Sailor Creek sagebrush area after the fall movements. The results are shown in figure 7.

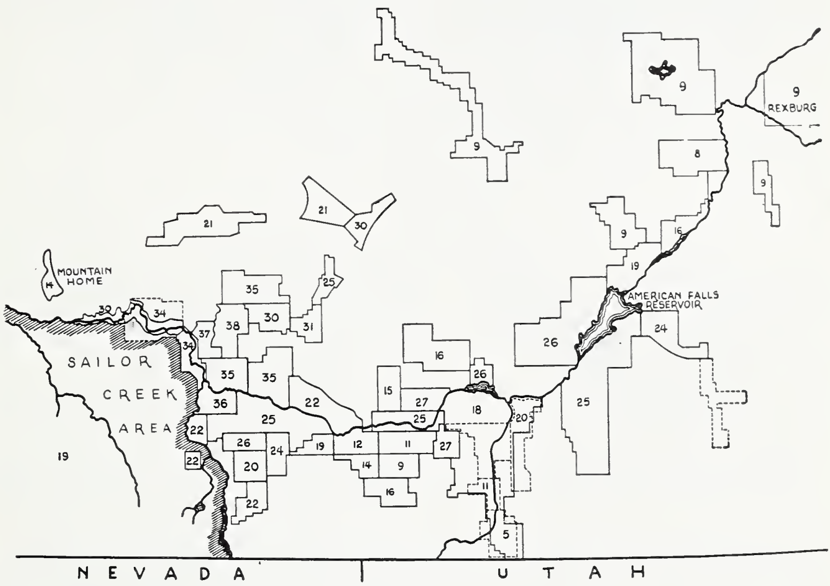

FIGURE 7.—Percentages of female beet leafhoppers parasitized by Dorilaidae in 51 Russian-thistle summer breeding areas (numbers within rectangles or polyhedrons) compared with the Sailor Creek sagebrush overwintering area, 1934–37.

It is apparent that many large Russian-thistle areas in southern Idaho provide host plants for the development of enormous populations of the beet leafhopper during the summer. It is also evident that in the fall a fairly high percentage of the leafhoppers are parasitized by Dorilaidae, the average parasitization for the 4-year period being approximately 29 percent. When the Russian-thistle becomes dry in the fall, or when other unfavorable conditions develop, the insects move to other locations where there are green plants. The Sailor Creek sagebrush area is typical of such environments. Large numbers of parasitized beet leafhoppers reached these overwintering quarters, although not so many as unparasitized leafhoppers. The average parasitization of the leafhoppers in the overwintering area was 19 percent.

Because of limitations in the movement of leafhoppers containing larvae of various parasites, locations of high parasitization should indicate nearness to overwintering areas from which the leafhoppers disperse in the spring. During the falls of 1934–37 there were three areas in southern Idaho (fig. 8) where percentages of parasitization

were higher than in the surrounding areas. In the western part the highest fall parasitization occurred northeast of the important Sailor

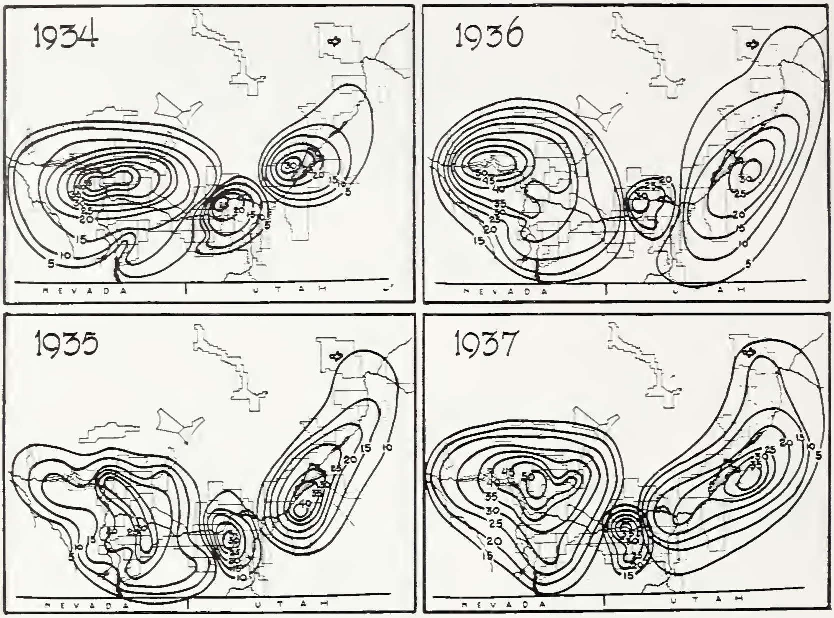

FIGURE 8.—Parasitization of female beet leafhoppers by Dorilaidae in Russian-thistle summer breeding areas of southern Idaho, 1934–37. Contour lines represent parasitization intervals of 5 percent.

Creek overwintering area. In the eastern part the highest concentration of parasites was in the vicinity of American Falls Reservoir. Large growths of flixweed (*Descurainia sophia* (L.) Webb) occurred near there, especially in the Aberdeen section, and possibly leafhoppers overwintered in protected spots made available by this host plant. The third concentration was centrally located and was the smallest. The high parasitization there could have resulted from parasitized leafhoppers overwintering in or near the beetfields or in protected places in the Albion foothills. These three concentrations were similarly located during each of the 4 years, and possibly indicate proximity to permanent overwintering and spring breeding areas of the beet leafhopper.

In recent years most of the Russian-thistle has been found on overgrazed rangeland along with annual mustards. This situation would favor the internal parasites, depending upon the extent to which the areas of Russian-thistle and spring mustards overlap and reduce the need for the insects to move.

Summary

Studies were made in southern Idaho from 1930 to 1937 to determine the effect of parasitization on the ability of the beet leafhopper (*Circulifer tenellus* (Baker)) to move long distances, and the effect of leafhopper movements on the dissemination and distribution of its parasites.

In southern Idaho large numbers of beet leafhoppers develop during the summer on Russian-thistle. In the fall when the plants become dry or other unfavorable conditions develop, the leafhoppers move to the sagebrush areas. Populations develop during the spring on green tansymustard and other annual plants within the sagebrush areas, and when these annuals dry the leafhoppers move to the cultivated fields and Russian-thistle areas, where they spend the summer. These flights often carry the insects many miles.

In southern Idaho the leafhoppers are parasitized primarily by species of Dryinidae, Stylopidae, and Dorilaidae. The first two depend almost entirely on the movement of the leafhopper for their dissemination. In contrast, the Dorilaidae are strong fliers, and many undoubtedly fly into the various breeding areas or are carried there by air currents. However, the most common method of dissemination for this family is also as larvae within the bodies of the leafhoppers.

Large numbers of leafhoppers were collected before and after the fall and spring movements to determine the comparative percentages of parasitization, and to estimate the loss in parasites associated with the movement of the hosts from one breeding area to another.

Before the fall movement, 29 percent of the dissected leafhoppers in the Russian-thistle areas were found to be parasitized as compared with 19 percent of those that reached the overwintering sagebrush area. The parasite larvae were small, and did not greatly handicap the leafhoppers in short-distance movements. Of the parasitized leafhoppers observed at the time of the fall movement, 98 percent were infested with Dorilaidae, practically all of which were *Tömösváryella vagabunda* (Knab). In the fall movements of 1934–37 there was a slight tendency toward decreased parasitization as the distance into the sagebrush area increased.

The spring movement of the beet leafhopper in southern Idaho usually occurs during the first half of June. At that time the dorilaid larvae vary in size, and the presence of a large larva in the body of the leafhopper affects its ability to fly. In the spring of 1937 there was a significant reduction in the percentage of parasitization of the disseminating leafhoppers as the distance into the cultivated area increased, due to the shorter distances traveled by leafhoppers containing large larvae.

There is, in general, a negative correlation between the percentage of parasitization and the distance traveled by the host leafhopper, and where long-distance movements occur these reductions may be of great importance. When transferring from one breeding ground to another the beet leafhopper often travels 200 to 300 miles or more. In these long-distance movements it is possible that few parasitized spring-generation leafhoppers would reach the new breeding area. Internal parasites of insects that move long distances are always at a disadvantage in reducing host populations. Before the parasites have time to reduce their numbers greatly, the leafhoppers move, with a consequent decrease in parasites.

In recent years most of the Russian-thistle has been found on overgrazed rangeland along with annual mustards. This situation would favor the internal parasites, depending upon the extent to which the areas of Russian-thistle and spring mustards overlap, and reduce the need for the insects to move.

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